RESPONSE OF MIGRANT AND RESIDENT BIRD COMMUNITIES TO ANTHROPOGENIC DISTURBANCES IN SHIWALIK LANDSCAPE, UTTARAKHAND, INDIA

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Frequent compounded perturbations in terms of lopping, grazing, biological invasions, firewood and non-timber forest product (NTFP) collection gradually alters the habitat, and consequently dependent biotic communities. However, it is quite difficult to quantify these disturbances due to their high frequency, low intensity, and interaction among themselves. In order to quantify and investigate the impact of such disturbances on the habitat of resident and migrant birds, we carried out a study in the dry forest of Rajaji National Park in the Shiwalik landscape. Grazing and firewood collection emerged as the major disturbance in the study area, which decreased linearly from the edge to the interior of the forest. Disturbance altered the structural components of the vegetation; however, we did not find major changes in the vegetation composition. Canopy opening due to lopping disturbance facilitated the growth of *Lantana camara* in the study area. Ninety percent of the migrant bird community wintering in the study area belonged to the insectivorous guild. Out of 18 migrant species observed during the entire study period, 44% belonged to understorey-insectivores guild and 33% to canopy-insectivores. However, in terms of abundance 67% of the migrants pertained to the canopy-insectivores guild. Guild composition in resident birds was more varied with a total of 11 guilds, and trunk-bark feeder guild comprised the maximum number of species (20%). Species richness of both migrant and resident birds did not change much with any of the disturbance components. However, densities of resident birds increased with increased lopping and timber extraction in the study area during winter. Resident and migrant birds exhibited similar distribution patterns across different disturbance gradients indicating equivalent sensitivity to disturbances.

Key words: bird communities, Rajaji National Park, disturbances, heterospecific attraction

INTRODUCTION

Conservationists throughout the world are concerned about the declining number of migratory bird species (Calvert *et al.* 2009; Faaborg *et al.* 2010; Terborgh 1989; Wilcove and Wikelski 2008). It becomes difficult to determine the actual cause of migratory bird decline due to the variety of habitat use during different phases of life cycle (Faaborg *et al.* 2010). Habitat conditions in breeding, stopover and wintering sites are the key factors influencing survival and reproduction of migrants (Sherry and Holmes 1995). Research and management of migrant birds generally focuses on conditions in the breeding sites where they spend less time than their wintering sites. Protection and food resources in wintering areas ensure survival of individuals as well as nutrient build up for migrating back to the breeding grounds and possibly for future reproduction (Calvert *et al.* 2009). Some of the migratory birds spend more time in their wintering and stopover sites than their breeding sites. Therefore, habitat degradation in wintering sites could have detrimental effect for migratory birds (Terborgh 1989). During their stay in wintering sites, migrants interact and share resources with resident bird species. Due to their high abundance in secondary forest and degraded areas, migrants are assumed to be subordinate to resident bird species (Powell 1980; Rappole *et al.* 1983). However, Terborgh (1989) emphasised that migrants are not weedy opportunists in tropical forests, but an integral part of the overall bird community.

Rapid degradation of wintering areas of these species puts direct pressure on the survival and future reproduction of migrants. Subsistence use of forest by the communities residing in and around protected areas (PAs) is one of the major causes of the degradation of forests throughout the world. The situation is more alarming in developing countries like India where approximately 69% of the PAs are inhabited by local communities whose population was put at *c.* 4.5 million (Kothari *et al.* 1989). These communities depend on forest not only for their survival, but also for livelihood. Removal of vegetation biomass during these disturbances modifies the habitat structure and composition (Daniels *et al.* 1995; Kumar and Shahabuddin 2005; Murali *et al.* 1996; Sagar *et al.* 2003), which in turn has implications for the survival and reproductive fitness of the biotic communities (Shahabuddin and Kumar 2006). Information about distribution of migrants in different quality wintering habitats, in relation to resident species, is still lacking from tropical countries, including India.

In this study we first investigated the impact of extractive disturbances on vegetation structure and composition in the dry plain Sal forest of Rajaji National Park

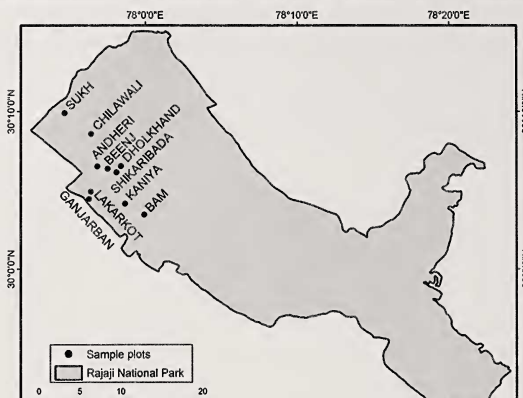

Fig. 1: Rajaji National Park, showing location of the sampling plots

and then examined the patterns of distribution of non-breeding winter migrants and resident bird species across different disturbance gradients. Finally we explored the relationship between resident and migrants across all the sampling plots to test how one community distributes itself in relation to others.

STUDY AREA

The study was conducted in Rajaji National Park (29°52' –30°15' N; 77°55'–78°5' E), one of the most important protected areas of India for the conservation of two charismatic mammal species, i.e. Tiger *Panthera tigris* and Asian Elephant *Elephas maximus*. Located in the north-western region of Shiwalik Hills of Uttarakhand state, Rajaji National Park (hereafter RNP) covers an area of 820 sq. km.

Intensive study sites were located in the dry plain Sal forest (5B/C1 B) in the southern side of RNP (Champion and Seth 1968). This region is characterised by its serrated topography, with a number of steep ridges which emerge from the main Shiwalik ridge and have narrow valleys between them. Sal *Shorea robusta* forms the climax species of the forest succession and is the dominant species of this forest type. Most typical associates of Sal in this forest are *Terminalia tomentosa*, *Terminalia bellerica* and *Lagerstroemia parviflora* in the middle canopy. The understorey constitutes *Mallotus philippensis*, *Ehretia laevis*, *Cassia fistula*, *Miliusa velutina*, and *Holarrhena antidysenterica*. *Clerodendrum viscosum*, *Murraya koenigii*, *Colebrookea oppositifolia*, and *Adhatoda vasica* form the shrub layer. *Lantana camara* (hereafter lantana), an exotic invasive, occupies a large area in this forest type and forms dense thickets in disturbed areas.

This area has been home to a nomadic pastoral community – the Gujjars – for at least the last eight decades (Kumar 1995). Gujjars rely heavily on the forest for lopped fodder resources for their livestock to support their dairy product based economy, and for fuel and timber requirements. Till 2003, as much as 86% of the RNP was open to the Gujjar community for lopping and grazing. Indiscriminate lopping year after year resulted in tree mortality and weed infestation. In the past, Gujjars used to leave their dwellings in the landscape with the advent of summer around April for high altitude meadows in the Himalaya, where they would stay until October. However, now partly due to the fact that local communities in the Himalaya do not want to share their resources with the Gujjars and partly owing to socio-economic changes within the community itself, most of them have abandoned this traditional migration. The reduction in migration has resulted in their increased demands on the RNP landscape. However, a major relocation drive, started almost a decade back, of the Gujjar families from RNP to Haridwar

(Pathri and Gaindikahta resettlement colonies) helped in considerable release of pressure on the forest. As a result, some ranges have little to moderate disturbance by Gujjars, whereas others are completely undisturbed. Another major disturbance in this area is the collection of non-timber forest products (NTFP), including Bhabar grass *Eulaliopsis binata* (Dhaundiyal 1997). Bhabar grass contributes significantly to the subsistence economy of the large number of people living on the boundary of the dry plain forest. However, due to restrictions imposed under the Wildlife (Protection) Act, Bhabar grass collection was banned inside the Park. Therefore, the relocation of Gujjars, and stringent implementation of the law by forest officials, has created a gradient of disturbances in the study area.

The bird diversity of this region is even more remarkable, with 312 species of birds (Pandey *et al.* 1994). Of these, 144 are residents, 89 are migrants, 53 are altitudinal migrants, and the status of 18 is unknown.

METHODS

1. Site selection

To find out the relationship between disturbance, vegetation and bird communities sampling plots were chosen across a gradient of human disturbance through a preliminary survey in dry plain Sal forest (Fig. 1) of RNP. A total of 10 sampling sites were chosen across the entire landscape. At each site a 1 x 1 km representative area, which was reasonably homogenous, was delineated (grid) as sampling plot, leaving a buffer of at least 250 m from the boundary to negate 'edge effects'. Each plot again had three parallel line-transects at a distance of 250 m from the edge of the grid. On each transect three points were marked at a distance of 250 m (Fig. 2). At each point, nested circular plots were established for enumerating vegetation structure and composition, and anthropogenic disturbances. The same points were used to collect data on bird composition and abundance through the variable radius point transect method. A total of 89 points were used for data collection on vegetation disturbance and birds.

2. Vegetation Sampling

Around each intensive sampling point concentric 10 m and 5 m radius plots were laid to enumerate vegetation structure and compositional attributes for the tree and shrub layer respectively. In total, 89 vegetation plots (one plot had 8 intensive sampling points) were laid for both tree and shrub layer variables during two winter seasons (2010-2011). All woody vegetation GBH 20 cm or above was considered as trees. In each 10 m radius plot number, identity of species,

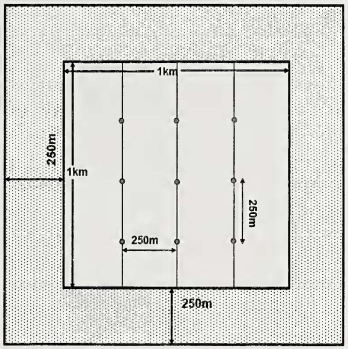

Fig. 2: Diagrammatic representation of the sampling plot. Each plot had an area of 1 sq. km with a buffer of 250 m on each side. Intensive sampling points were laid at a distance of 250 m from the edge of the plot (shown as points)

GBH, canopy spread in two perpendicular diameters, and top and bottom height of canopy for each tree was recorded. Percent canopy cover was measured directly by means of a spherical densitometer, as the average of crown-cover readings taken from the centre of the plot in four cardinal directions.

Shrub variables were measured in circular plots of 5 m radius nested in the tree plots mentioned above. All woody vegetation less than 20 cm GBH was considered as shrubs. In each shrub plot, species identity, number of individuals, height and canopy spread in two perpendicular diameters for each shrub was recorded.

3. Disturbance quantification

All the disturbance variables were quantified in the 20 m radius plot nested around the intensive sampling plot. Parameters used for quantification of disturbance were percentage of lopped trees (PERLOPP), lopping intensity on each tree (AVSCLOPP), number of dung pats (CATTDUNG), number of human trails passing through the plot (TRLN), percentage of grazing (GRZ), and number of cut trees (CUTTR) and cut stumps (CUTST). Intensity of lopping on each tree was estimated as an index. According to this index an intact tree with no sign of lopping gets zero value, a tree with less than half its branches lopped gets value 1, a tree with 50% lopped branches gets value 2, more than half of the branches lopped gets 3 and a tree with all branches lopped gets 4 (Shahabuddin and Kumar 2006).

4. Avifaunal sampling

Variable radius point transect method (Bibby 2000) was used to collect data on bird communities. All the points were at least 250 m apart from the centre of all the other points in the plot to avoid overlaps in bird encounters (Hansen *et al.* 1995). Birds were observed for 5 minutes at each point after an interval of 2 minutes from reaching the point (settling down time). It was observed that there were no substantial additional observations beyond the 5-minute period. Moreover, the chances of double counting get enhanced for longer periods. All birds seen or heard were recorded.

Additionally, the number of individuals and distance from the observer were also recorded. Distance was recorded using a laser rangefinder. All the birds were identified using standard field guides (Grimmett *et al.* 1999). All the point transects were conducted by a single observer (M. Kaushik) to avoid observer bias. Only the birds using the area during the count were recorded and all the birds that were transient were ignored.

Bird observations were made between 0.5 and 3 hrs after sunrise when visibility and bird activity is the highest (Raman *et al.* 1998). Only one plot comprising nine points was selected for bird sampling each day. All the points were visited for three mornings. To capture the maximum species variation during the study period, all the points were visited after a gap of at least seven days. Again, within a plot, the order of visiting the points was reversed each morning to negate the bias due to flushing of birds by the observer. Data of two winter seasons (2010-2011) was used for analysis.

STATISTICAL ANALYSIS

Principal component analysis (PCA) was carried out with the seven measured disturbance variables to extract the major disturbance regimes in the study area. All the disturbance variables were z-standardised (mean zero and unit standard deviation) before carrying out the PCA so that all variables got equal weight (Jongman *et al.* 1995; McGarigal *et al.* 2000). PCA was done using software SPSS (Version 16). Only those principal components with eigenvalue greater than one were selected. Pearson correlation was carried out between PCA scores of disturbance variables and vegetation variables (structural and compositional) to find out the relationship between them. Species richness and diversity were estimated for migrant and resident bird species through the point count data using software Pc-Ord version 4 (McCune and Mefford 1999). The density of resident and migrant birds was estimated using software Distance 5 (Thomas *et al.* 2010). Scatter plots in conjunction with generalised linear model (GLM) were used to investigate the response of both migrant and resident bird species to major disturbances in the study area. Distance of all the sampling plots was calculated using software ArcGIS. Correlation was done between different disturbance components and distance of sampling plots from the forest edge.

RESULTS

Disturbance variables were summarised using principal component analysis (PCA) and sampling plots were plotted on the first two disturbance components. Results of PCA extracted three major disturbance factors (i.e., grazing and fodder collection, lopping pressure and timber extraction), which explained 74% of the total variation in disturbance variables. Variation explained was 31%, 27%, and 16% by PC1, PC2, and PC3 respectively. Most of the variables positively contributed to the first principal component with the exception of variables related to timber extraction. The loadings for the second axis were low for the metrics related with livestock and firewood collection, but high for lopping disturbance (Table 1).

Segregation of sites using PCA corresponded closely with that made *a priori* by investigators. Of all the sampling plots, Lakarkot had the highest pressure due to grazing and firewood collection, followed by Andheri. Lopping pressure was highest in the Ganjarban and Sukh plots. Shikaribada showed lowest mean and variance for both disturbance gradients (Fig. 3).

Although all the disturbance components showed a declining trend with increased distance from the edge (grazing and fire wood collection: $r = -0.40$, $p = 0.25$; timber extraction: $r = 0.47$, $p = 0.16$), the trend was significant only for lopping pressure ($r = -0.85$, $p = 0.001$).

Table 1: Metric loadings for all three principal components extracted through Principal Component Analysis

	PC1	PC2	PC3
Grazing and Firewood collection			
TRLN	0.74	0.09	-0.04
CATTDUNG	0.64	0.05	0.47
CUTTR	0.76	-0.08	-0.12
GRZ	0.75	0.27	-0.01
Lopping pressure			
AVSCLOPP	0.07	0.95	0.03
PERLOPP	0.12	0.94	0.07
Timber extraction			
CUTST	-0.11	0.06	0.93

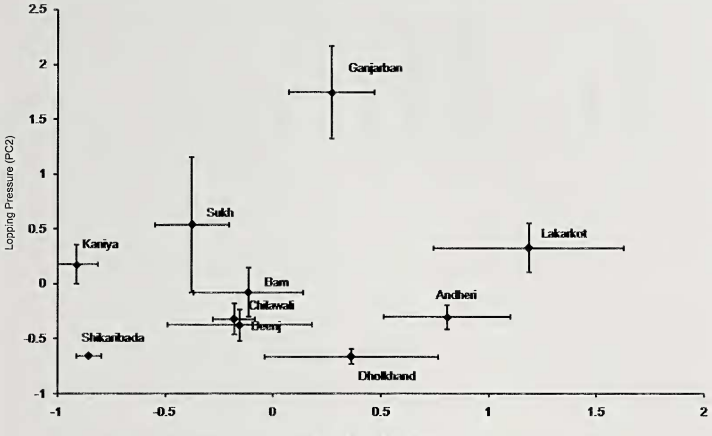

Fig. 3: Mean and standard error of two extractive disturbance components across different sampling plots

On correlating the vegetation variables (structural and compositional) we found that, percentage canopy cover was negatively related to grazing and firewood collection (PC1), whereas a strong positive relationship was observed between lopping pressure (PC2) and tree basal area. Interestingly, Lantana density also showed a significant positive relationship with lopping pressure. None of the vegetation attributes was found to be associated significantly with timber extraction (PC3). Both tree and shrub diversity did not show any significant relationship with any of the PCs (Table 2).

A total of 18 migrant and 66 resident bird species were detected within the study area across all the sampling plots over a two year period (Appendix 1). Richness of resident bird species was highest in the least disturbed plot of Shikaribada (41) and lowest in the moderately disturbed plot of Beenj (24). Highest richness of migrant birds was found in a moderately disturbed plot of Bam (13), and Beenj had the lowest migrant richness (4). Average density of migrants and resident birds for the study area was 2.9 ±0.08 (indi/ha) and 23.6 ±0.08 (indi/ha) respectively. Densities of both resident and migrant was highest in the disturbed plot Sukh (resident = 55.5 ±18.6, migrant = 22.9 ±20.6), and lowest in the moderately disturbed plot of Dholkhand (resident = 8.3 ±15.25, migrant = 3.3 ±20.4). The segregation of species in both the communities on the basis of their foraging guild revealed that resident birds had 11 guilds, whereas migrants belonged to only 6 guilds. Out of 18 migrant species observed during the entire study period, 44% belonged to understorey-insectivores guild and 33% to canopy-insectivores. Guild composition in resident birds was broader and trunk/bark feeder guild contributed the maximum number of species (20%) followed by understorey-insectivores (17%). However,

Table 2: Pearson's correlation between principal components of disturbance and vegetation (structural and compositional) variables

	Tree basal area (m^2)	Tree crown cover (m^2)	% canopy cover	Tree density	Shrub density	Shrub crown cover (m^2)	Lantana density	Shrub diversity	Tree diversity
PC1	0.17	-0.31	-0.65*	-0.19	0.40	-0.27	-0.09	0.29	0.04
PC2	0.81**	0.18	-0.29	0.27	-0.45	-0.01	0.67*	0.33	0.54
PC3	0.25	0.35	0.28	0.15	-0.20	0.11	0.27	-0.09	0.18

Statistically significant correlations between disturbance and vegetation variables are indicated with symbol* (*=p<0.05 and **=p<0.01)

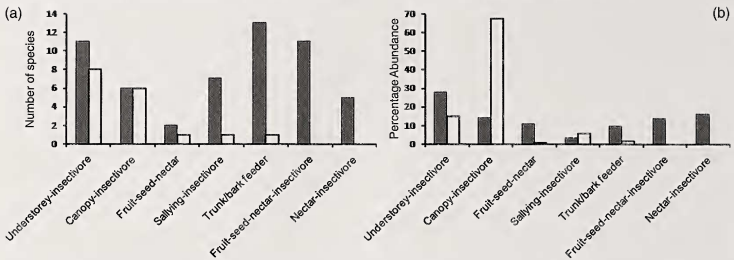

Fig. 4: Guild composition of resident and migrant bird species in terms of (a) species richness and (b) abundance

in terms of abundance, 67% of the migrants were canopy-insectivores and 14% were understorey-insectivores. Even in the resident bird community, 28% of the total abundance was contributed by understorey insectivores, followed by the canopy-insectivores (14%). For the graphical representation, we included guilds with more than 1% abundance (Fig. 4).

Both resident and migrant bird species richness showed declining trends with all the disturbance components, however, the results were not significant (Table 3). Densities of resident birds showed a declining but non-significant trend with grazing and firewood collection (PC1). A significant increasing trend was found between resident bird density and lopping disturbance (PC2), as well as timber extraction (PC3). Densities of migrant birds followed the same trend as resident birds, however, the relationship was only slightly significant for timber extraction (PC3, Fig. 5).

A positive correlation was found between the density estimate of migrant and resident species ($r = 0.65$, $p = 0.04$, Fig. 6a). Similarly a strong positive correlation was found between the resident and migrant species richness ($r = 0.78$, $p=0.007$) and diversity ($r = 0.72$, $p=0.01$, Fig. 6b).

DISCUSSION

Grazing and firewood collection were the major disturbance factors in the study area as they constituted the first principal component and explained the maximum variation in disturbance variables. Most of the different indicators used to quantify disturbance in this study were positively correlated with each other, which indicates concurrent nature of small-scale disturbances (Karanth *et al.* 2006; Martorell and Peters 2005; Singh 1998). Lopping pressure inside the Park depends largely on the availability of tree species preferred by Gujjars. However, areas preferred for lopping are not nececessarily subject to other disturbance activities. Therefore, lopping constituted a separate disturbance component.

In this landscape, disturbance intensities are influenced by flat terrain or accessibility, proximity to human habitation (Kurien *et al.* 2007) and degree of protection. In our study, we found that all disturbances declined as we moved deeper into the forest, which is coherent with other such studies (Karanth *et al.* 2006; Kurien *et al.* 2007; Thapa and Chapman 2010). Segregation of sampling plots across the first two principal

Table 3: Results of generalised linear model (GLM) for the resident migrant richness and density across different disturbance components

		Resident			Migrant		
Community attributes	Disturbance component	ß	SE	Z	ß	SE	Z
Richness	PC1	-0.003	0.09	-0.004	-0.01	0.17	-0.08
	PC2	-0.05	0.08	-0.65	-0.15	0.17	-0.90
	PC3	-0.27	0.18	-1.51	-0.56	0.35	-1.61
Density	PC1	-0.48	0.33	-1.4	-0.42	0.28	-1.50
	PC2	0.62	0.26	2.3*	0.43	0.25	1.72
	PC3	1.59	0.47	3.4*	1.01	0.51	1.95

Parameter estimate of the best model showing regression coefficient ±SE, z-statistics and significance (**= p= 0.001,*= p=0.01)

components revealed that sampling plots such as Lakarkot and Ganjarban near the Park boundary suffered higher disturbance in terms of grazing, firewood collection, and lopping. In contrast, plots such as Shikaribada in the forested interior of the Park boundary experienced negligible disturbance.

Despite being cryptic, small extractive disturbances are known to bring severe changes in the habitat structure (Kumar and Shahabuddin 2005; Ramírez-Marcial *et al.* 2001; Sagar *et al.* 2003; Singh *et al.* 1997), which effects regeneration and stand composition (Beckage and Clark 2003). All vegetation structural variables did not show a strong relation with disturbance gradient, but a negative trend was evident for the foliage cover with first two disturbance components. Canopy opening and overgrazing lead to more sunlight reaching the forest floor and could decrease soil moisture and increase the temperature. Such overall increase in xeric conditions would be more detrimental for dry forest, as very few species would be able to cope with extremely high temperature and increased irradiance (Belnap 1995; Milton and Dean 1995; Valone *et al.* 2002). Enhanced understorey growth increases the fodder and firewood availability in open areas, therefore these areas showed higher disturbance due to grazing and firewood collection.

Canopy openings increase resource availability and also modify the microclimate, which is consistent with the disturbance patch invasion model (Gentle and Duggin 1997). According to this model, removal of competitive biomass and disruption of interspecific competitive interactions creates patches of increased resources. Many exotic weeds benefit from such disturbances and exert substantial pressure, including competition, on the native species (Fischer *et al.* 2006; Harper *et al.* 2005). In our study area, increased lopping pressure intensified Lantana density, supporting the disturbance patch invasion model. Such an increase in lantana cover will provide dense shade which would prevent establishment of herb and tree seedlings, eventually resulting in overall structural and compositional change in the forest (Sharma and Raghubanshi 2006).

Compared to migrants, residents showed a stronger relationship with disturbance variables. In addition, large scale disturbances such as timber extraction affected the resident bird richness more strongly than the small scale disturbances during winter. Insectivory appears to be the major foraging strategy during the winter, as the majority of migrants (90%) as well as the residents are insectivores. The majority of the resident birds appear to utilise the understorey vegetation layer

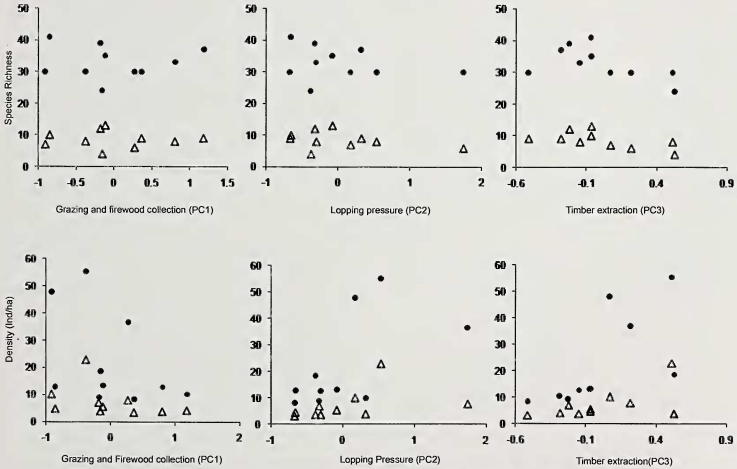

Fig. 5: Scatter plots between bird community parameters (richness and density) and extractive disturbance components. Resident bird community is represented by closed circles and migrant bird community by open triangles

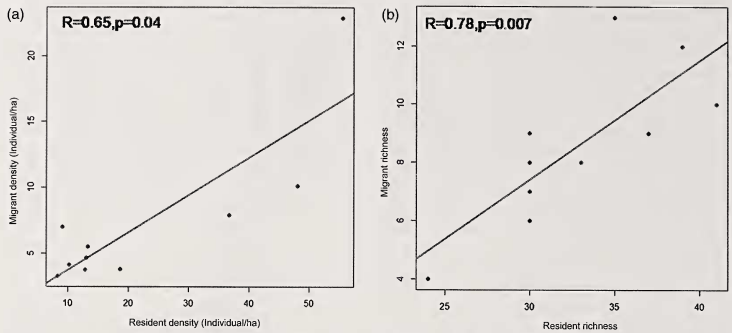

Fig. 6: Pearson Correlation between resident and migrant (a) density and (b) species richness

during the food-scarce winter season. This could be one of the mechanisms of accommodation of migrant birds during food shortage, as 67% of the migrant birds foraged in the canopy.

Past studies have suggested that migrants are more flexible than residents in their habitat use and are potentially more tolerant of disturbance (Greenberg 1995; Hutto 1989; Karr 1976). Yet there is evidence to prove that both migrants and residents share similar distribution pattern across habitat gradients (Emlen 1980; Petit *et al.* 1992). Smith *et al.* (2001) during their study in the Yucatan peninsula found that all stages of successional forest supported highly similar bird assemblages and did not differ in bird abundance or diversity. Moreover, residents and migrants distributed themselves similarly across successional gradients. Similarly, a study by Wallace *et al.* (1996) in the Cuban forest revealed that numbers of migrant and resident species were significantly positively correlated. Our study from Shiwalik landscape also follows a similar trend. Both species richness and density of migrant and resident birds were significantly positively correlated. This suggests that both resident and migrant birds might be equally tolerant or sensitive to disturbances.

Another possible explanation for the strong positive association between resident and migrant birds could be attraction between the two communities. Mönkkönen *et al.* (1990) hypothesized that migrants use resident birds as cues to profitable breeding sites and they called this phenomenon "heterospecific attraction". In experimental studies in boreal forests of North America and Europe, both richness and densities of migrants increased with increasing resident densities (Forsman *et al.* 1998; Mönkkönen *et al.* 1997). Similarly, a study conducted on resident Titmice and Pied Flycatcher in Finland showed that migrant flycatchers were attracted to the presence of Titmice and accrued benefits from this (Forsman *et al.* 2002). However, all studies on heterospecific attraction are conducted during the breeding season and there are no studies to verify this phenomenon in wintering sites. Still, it could be one of the most likely explanations for strong correlation between two bird communities. Such positive interaction between two potential competitors is suggested as highly beneficial for the migrants and neutral or beneficial for the residents (Forsman *et al.* 2002; Forsman *et al.* 2007; Mönkkönen and Forsman 2002). However, more studies on the interaction between resident and migrant birds in their wintering areas will strengthen our observation.

All these studies suggest that both migrant and resident bird species respond similarly to disturbance. These broad generalisations, however, should not be used for formulating conservation strategies for both groups. Different foraging guilds and individual species could vary significantly in their response to habitat disturbance, demanding specific conservation attention.

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Appendix 1: Bird species abundances recorded in 10 sampling plots in the dry forest of Rajaji National Park

Bird species	Sampling plots										Feeding Guild
Migrant Species	1	2	3	4	5	6	7	8	9	10	
Certhia himalayana	0	1	2	2	1	0	1	1	0	1	TBF
Anthus hodgsoni	8	5	0	0	0	0	0	39	9	0	GI
Phoenicurus coeruleocephala	0	0	0	3	0	0	0	0	0	0	UI
Saxicola ferreus	5	0	0	0	0	1	0	7	2	0	UI
Ficedula parva	4	2	0	8	3	0	1	8	0	0	UI
Ficedula strophiata	1	1	0	0	2	1	0	0	2	0	UI
Ficedula tricolor	0	4	0	2	0	5	0	0	2	3	UI
Phylloscopus fuscatus	0	2	0	0	0	0	0	0	0	1	UI
Seicercus whistleri	3	6	0	6	2	0	1	0	4	0	UI
Phylloscopus xanthoschistos	17	24	7	24	18	14	4	9	26	9	CI
Phylloscopus humei	24	30	15	30	27	6	16	24	35	27	CI
Phylloscopus chloronotus	1	0	0	8	3	0	1	2	0	0	CI
Phylloscopus tytleri	0	0	1	0	0	1	1	0	0	0	CI
Phylloscopus occipitalis	0	0	0	0	0	0	0	0	0	3	CI
Hypsipetes leucocephalus	0	0	0	3	0	0	0	0	0	0	GI
Culicicapa ceylonensis	0	6	0	6	4	0	0	1	8	11	SI
Sylvia curruca	0	4	0	3	0	0	0	5	1	0	CI
Zoothera dauma	0	0	0	0	0	1	0	0	0	0	UI
Resident species											
Spizaetus cirrhatus	0	0	0	0	0	0	0	3	5	0	R
Spilornis cheela	0	1	0	1	0	0	0	1	0	0	R
Accipiter nisus	0	0	0	0	0	1	0	0	0	0	R
Pernis ptilorhynchus	0	0	0	2	0	0	0	0	0	0	R
Accipiter badius	0	0	0	0	0	0	0	0	0	1	R
Aegithina tiphia	3	4	1	0	0	1	2	0	2	0	CI
Buceros bicornis	0	0	0	0	2	0	0	0	6	0	FI
Ocyceros birostris	0	0	0	2	0	1	0	2	0	0	FI
Anthracoceros albirostris	4	61	0	7	7	0	1	0	18	0	FI
Hemipus picatus	9	0	8	5	14	4	1	0	26	0	SI

Appendix 1: Bird species abundances recorded in 10 sampling plots in the dry forest of Rajaji National Park (*contd.*)

Bird species	Sampling plots										Feeding Guild
Migrant Species	1	2	3	4	5	6	7	8	9	10	
Coracina macei	0	0	0	0	0	0	2	1	4	0	CI
Pericrocotus flammeus	0	0	0	2	0	0	0	0	0	0	CI
Pericrocotus cinnamomeus	111	74	53	60	80	10	35	54	115	25	CI
Chloropsis aurifrons	0	2	0	0	0	0	0	0	0	0	CI
Orthotomus sutorius	7	10	2	3	0	2	2	6	3	1	UI
Prinia hodgsonii	182	64	59	98	62	21	64	157	50	32	UI
Chalcophaps indica	0	0	0	1	0	0	0	0	0	0	G
Corvus macrorhynchos	5	7	0	6	0	4	7	4	10	11	O
Urocissa erythrorhyncha	0	0	0	0	1	0	0	1	1	0	O
Dendrocitta vagabunda	4	12	7	18	3	3	4	15	16	14	O
Dicaeum erythrorhynchos	0	1	0	0	0	0	0	0	0	0	NI
Dicaeum agile	2	0	0	6	2	0	1	0	1	0	NI
Dicrurus macrocercus	0	0	0	0	0	0	0	2	0	0	SI
Dicrurus hottentottus	0	0	0	0	0	0	1	3	0	0	FSNI
Dicrurus caerulescens	7	3	3	8	3	1	3	0	5	12	SI
Halcyon smyrnensis	0	0	0	0	0	0	0	1	0	0	SI
Megalaima zeylanica	0	0	0	0	0	0	0	0	0	1	FI
Megalaima haemacephala	1	1	0	3	0	0	0	0	7	0	FSNI
Megalaima lineata	0	15	0	2	5	0	1	1	4	0	FI
Nyctyornis athertoni	0	2	0	1	0	0	0	0	0	0	SI
Saxicola caprata	0	0	0	0	0	1	0	0	0	0	UI
Cyornis tickelliae	1	9	0	0	0	1	1	3	2	2	SI
Copsychus malabaricus	1	0	0	2	0	0	0	0	0	0	UI
Aethopyga siparaja	1	3	0	2	4	2	0	2	4	0	NI
Nectarinia asiatica	0	0	0	2	0	0	0	0	0	1	NI
Oriolus xanthornus	1	9	2	7	7	14	8	5	6	7	FI
Parus major	41	27	18	32	59	11	17	25	27	17	TBF
Pavo cristatus	0	7	0	0	0	0	0	5	0	0	O
Lophura leucomelanos	0	0	0	0	0	0	0	0	2	0	UI
Gallus gallus	1	25	3	1	0	10	0	0	1	2	UI
Dinopium benghalense	5	3	1	5	2	1	4	3	5	1	TBF
Dendrocopos macei	3	3	0	9	1	3	3	2	6	2	TBF
Chrysocolaptes lucidus	0	0	1	6	4	0	0	5	1	1	TBF
Dendrocopos canicapillus	8	4	6	5	6	1	4	8	2	4	TBF
Picus canus	0	0	0	0	0	0	0	0	1	0	TBF
Dinopium shorii	0	0	1	2	0	0	0	0	0	1	TBF
Micropternus brachyurus	0	0	0	2	0	0	0	0	0	0	TBF
Picus sqamatus	0	0	0	0	1	0	0	0	0	0	TBF
Picus xanthopygaeus	2	0	0	1	0	0	1	1	0	0	TBF
Chrysocolaptes festivus	0	0	1	0	4	0	0	0	0	0	TBF
Psittacula cyanocephala	12	20	1	0	4	6	0	6	6	4	G
Psittacula krameri	68	50	77	43	32	30	68	78	23	3	FSN
Pycnonotus leucogenys	13	72	12	0	4	62	35	21	9	0	FSNI
Pycnonotus cafer	0	54	0	0	10	53	8	8	77	4	FSNI
Riphidura albicollis	5	4	0	4	2	0	1	1	4	7	SI
Sitta cinnamoventris	4	0	8	6	8	1	1	1	8	4	TBF
Sitta frontalis	0	0	3	1	1	0	1	0	3	0	TBF
Glaucidium radiatum	2	1	0	1	0	0	0	0	1	1	R
Acridotheres tristis	2	0	0	0	0	0	0	4	0	0	FSNI
Chrysomma sinense	0	0	0	0	0	10	0	0	0	0	UI
Tephrodornis pondicerianus	6	7	1	5	4	3	2	7	12	2	CI
Stachyris pyrrhops	2	9	0	0	0	4	0	4	4	12	UI
Turdoides striata	40	36	26	21	12	23	78	93	26	55	UI
Pellorneum ruficeps	0	2	0	0	0	0	0	0	0	0	UI

Appendix 1: Bird species abundances recorded in 10 sampling plots in the dry forest of Rajaji National Park (*contd.*)

Bird species	Sampling plots										Feeding Guild
Migrant Species	1	2	3	4	5	6	7	8	9	10	
Pomatorhinus erythrogenys	0	8	0	0	0	0	0	2	7	0	UI
Zosterops palpebrosus	88	274	15	62	89	9	44	22	66	87	NI

Sampling Plots: 1=Andheri, 2=Bam, 3=Beenj, 4=Chilawali, 5=Dholkhand, 6=Ganjarban, 7=Kaniya, 8=Lakarkot, 9=Shikaribada, 10=Sukh. Abbreviations used for Feeding guild: TBF=Trunk/bark feeder, GI=Ground insectivore, UI=Understorey insectivore, CI=Canopy insectivore, FI=Fruit insectivore, FSNI=Fruit seed nectar insectivore, FSN=Fruit seed nectarivore, SI=Sallying insectivore, NI=Nectar insectivore, O=Omnivore, R=Raptor

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